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Dyadic Variability in Mother-Adolescent Interactions: Developmental Trajectories and Associations with Psychosocial Functioning

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Abstract Dyadic variability is considered to be a key mechanism in the development of mother-adolescent relationships, and low levels of dyadic flexibility are thought to be associated with behavior and relationship problems. The present observational study examined heterogeneity in the development of dyadic variability in mother-adolescent interactions and associations with psychosocial functioning. Dyadic variability refers to the range of emotional states during interactions of mother-adolescent dyads. During five annual home visits, 92 mother-adolescent dyads (M age $T1 = 13$; 65.2 % boys) were videotaped while discussing a conflict, and they completed several questionnaires on adolescents' aggressive behavior and adolescents' and mothers' perceived relationship quality. Two types of dyads were distinguished: low variability dyads (52 %) and high decreasing variability dyads (48 %). Over time, high decreasing variability dyads were characterized by a broader emotional repertoire than low variability dyads. Moreover, these two dyad types had distinct developmental patterns of psychosocial adjustment. Over time, high decreasing variability dyads showed lower levels of adolescents' aggressive behavior, and

higher levels of perceived relationship quality than low variability dyads. These findings suggest that over time more dyadic variability is associated with less adjustment problems and a more constructive development of the mother-adolescent relationship. Adaptive interactions seem to be characterized by a wider range of emotional states and mothers should guide adolescents during interactions to express both positive and negative affect. Observing the dyadic variability during mother-adolescent interactions can help clinicians to distinguish adaptive from maladaptive mother-adolescent dyads.

Keywords Mother-adolescent interactions · Dyadic variability · State space grids · Psychosocial functioning

Introduction

The developmental phase of adolescence is marked by changes in the mother-adolescent relationship. From early to middle adolescence, the number of conflicts among mothers and adolescents increases, and maternal support and power decreases (De Goede et al. 2009). These changes are thought to accommodate adolescents' development towards greater autonomy and personal choice, and enable mothers and adolescents to establish a more egalitarian relationship (Laursen and Collins 2009; Smetana 2011). Changes in the content of mother-adolescent relationships may be accompanied by changes in structural aspects of the mother-adolescent relationships. An important structural aspect of relationships is the variability of dyadic interaction patterns, which refers to the range of emotional states of dyads during mother-adolescent interactions (Hollenstein and Lewis 2006; Lichtwarck-Aschoff et al. 2009). According to a dynamic systems approach, dyadic

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variability is considered to be an important factor in relationship changes, because this variability allows dyads to reorganize interaction patterns (Fogel 1993; Thelen and Smith 1994). High levels of dyadic variability may enable mother-adolescent dyads to adapt to relationship challenges and opportunities that arise during adolescence (Granic et al. 2003), and low levels of dyadic variability in mother-child interactions have been associated with both adjustment and relational problems (Granic et al. 2007; Lichtwarck-Aschoff et al. 2009). The major aim of the current observational study is to examine whether heterogeneity in the development of dyadic variability during mother-adolescent interactions is related to the development of adolescents' aggressive behavior, and adolescents' and mothers' perceived relationship quality.

Dyadic Variability During Adolescence

During the developmental period of adolescence, the mother-adolescent system reorganizes. Adolescents begin to re-evaluate the hierarchy of family roles and they try to assert more autonomy. This growing need for adolescent autonomy may give rise to discrepant expectancies of adolescents and mothers, which can result in more episodes of conflict. Mothers supporting adolescents' autonomy during conflict interactions enable the mother-adolescent system to realign beliefs and goals, to reduce conflict, and eventually to establish a more egalitarian relationship (Laursen and Collins 2009). So, adolescence can be viewed as a transitional phase for the mother-adolescent system.

According to a dynamic systems approach (Thelen and Smith 1994), development is characterized by major structural shifts during which interaction patterns of mother-adolescent dyads are reorganized into new forms. Higher levels of dyadic variability are thought to typify periods of change and reorganization (Fogel 1993). As conflicts are assumed to contribute to the development of autonomy and independence (Laursen and Collins 2009; Pinquart and Silbereisen 2002), higher levels of dyadic variability during these conflicts may be related to a more optimal reorganization of mother-adolescent interaction patterns (Granic et al. 2003). Mother-adolescent dyads that are able to express both positive and negative emotions during conflicts may be able to put across their point of view clearly and to adjust their perceptions accordingly, which enables them to develop more egalitarian interaction patterns. However, dyads that have a tendency to express a small range of emotions, even if these emotions are neutral or positive, might be characterized by a lack of sensitivity to interpersonal and contextual demands. Dyads that get stuck in negative emotional states during conflicts may not be able to solve the conflict and maintain a close relationship. Also, dyads that remain continuously in a mutual positive or

neutral emotional state during conflict interactions might not be adapting well to the emotional demands of such a context. So, it is thought that the expression of a wide range of both positive and negative emotions during conflict interactions is related positively to relational reorganizations during adolescence (Granic 2005). Dyadic variability is therefore thought to be a key mechanism in the development towards more egalitarian mother-adolescent relationships (Branje 2008; Lichtwarck-Aschoff et al. 2009).

From a dynamic systems viewpoint, dyadic variability is thought to characterize transitional periods and it therefore expected to be higher during adolescence when mother-adolescent relationships need to be reorganized. One study examined changes in the structure of mother-son interactions from preadolescence to middle adolescence, and indeed found an average peak in dyadic variability in mother-son dyads at age 13–14 (Granic et al. 2003). As dyadic variability during mother-adolescent interactions may change over the course of adolescence, it seems important to examine associations of development of dyadic variability with adjustment and relational changes during adolescence.

Dyadic Variability, Adjustment, and Relationship Quality

Dyadic variability is found to be related to psychosocial functioning, and it is thought that dyadic emotion regulation potentially can explain this link (Granic et al. 2007; Lichtwarck-Aschoff et al. 2009). Through interactions with parents, adolescents learn to express and to regulate their emotions (Gross 2007; Izard 2009). Dyads with low levels of variability have been labeled as “rigid”, and these dyads are thought to have difficulties with emotion regulation during interactions (Granic et al. 2007). In addition to an indirect association between lower levels of emotion regulation and higher levels of externalizing problems (De Rubeis and Granic 2012; Silk et al. 2003), there is also evidence for a direct association between levels of dyadic variability and aggressive behavior in childhood. Less dyadic variability at age three contributed to more externalizing problems at age five (Lunkenheimer et al. 2011), rigid mother-child interactions were associated with externalizing behavior problems in high risk children in kindergarten (Hollenstein et al. 2004), and more rigid mother-child dyads failed to show an improvement in children's aggressive behavior after treatment (Granic et al. 2007). Altogether, more dyadic variability during childhood is related to higher levels of children's aggressive behavior. There is no evidence yet for this link during adolescence, and therefore the current study will examine the longitudinal associations between dyadic variability and aggressive behavior over the course of adolescence.

Much less is understood about the link between dyadic variability and perceived relationship quality. Cross-sectional data showed that adolescent girls who were more emotionally variable perceived moderate levels of conflict with their mother whereas girls who were less emotionally variable perceived either very low or very high levels of conflict (Lichtwarck-Aschoff et al. 2009). Adolescents who were more rigid in emotional states across conflicts also had conflicts about a greater number of topics. These adolescents were stuck in a small emotional repertoire in different conflict discussions. So, these results suggest that experiencing a wider range of emotions is adaptive because it is associated with moderate levels of conflicts during early adolescence. Conflicts are thought to trigger relational reorganizations; and they generally are seen as healthy and adaptive patterns of interactions during adolescence (Laursen and Collins 2009). However, it is not known whether and how developmental changes in dyadic variability over the course of adolescence are related to developmental changes in adolescents' and mothers' perceived relationship quality. The current study will therefore examine these associations.

Research Aims and Hypotheses

The major aim of the present observational study is to examine the associations between heterogeneity in the development of dyadic variability during mother-adolescent interactions and the development of adolescents' aggressive behavior, and adolescents' and mothers' perceived relationship quality. To be able to target mother-adolescent dyads at greatest risk for adjustment and relationship problems, it is necessary to examine developmental pathways of dyadic variability. Therefore, we adopt a person-centered approach to first identify distinct dyadic variability trajectories, which can vary in terms of both the level of variability and its rate of growth or decline over time (Nagin 2005). Next, we will examine the longitudinal link between dyadic variability trajectories and aggressive behavior, perceived autonomy support and perceived conflict frequency. We expect that adolescents from mother-adolescent dyads with higher levels of variability over time will report lower levels of aggressive behavior over time than adolescents from mother-adolescent dyads with lower levels of variability over time (e.g., Lunkenheimer et al. 2011). Also, we expect that higher levels of dyadic variability over time are related to self-reported changes over time in the mother-adolescent relationship, such as more autonomy support and moderate levels of conflict (e.g., Lichtwarck-Aschoff et al. 2009). To examine these research questions, we employ five

consecutive annual waves of data from both observations and questionnaires of mother-adolescent dyads.

Method

Sample

This study uses data from the RADAR (Research on Adolescent Development And Relationships) project, an ongoing longitudinal study in the Netherlands that focuses on the development of relationships and problem behavior in adolescence. To date, six annual waves of data-collection have been completed among 497 adolescents and their parents. The present study used a subsample of 92 mothers and adolescents who were videotaped during five annual home visits. At the first wave, the mean age of the mothers was 44.87 years ($SD = 4.83$), and the mean age of the adolescents was 13.01 years ($SD = .52$). The sample consisted of 54 boys (58.7 %) and 38 girls (41.3 %). At the first wave, adolescents were in the first grade of junior high. Most adolescents lived in medium or high SES families (92.4 %).

Attrition in the observation sample was relatively low, namely 15.22 % from wave 1 to 5. *T* test and Chi-square analyses revealed no differences in age, gender, and family SES between participants that participated on all five waves and participants that dropped out of the study. Little's (1988) Missing Completely At Random (MCAR) Test produced a normed χ^2 (χ^2/df) of 1.04 which indicates a good fit between sample scores with and without imputation (Bollen 1989). Missing values were therefore estimated in Mplus using Full Information Maximum Likelihood (Enders and Bandalos 2001). We used Robust Maximum Likelihood Estimation to take into account the non-normal distribution of some of the data (Satorra and Bentler 2001).

Procedure

The participants were recruited from several randomly selected Dutch schools in the province of Utrecht, and the cities of Amsterdam, Rotterdam, The Hague, and Almere. Teacher screening and parent interviews were used to select the 497 families in the RADAR sample. The participants received written information describing the research project. At the first wave 102 mother-adolescent dyads were randomly selected from the total RADAR-sample to also participate in the annual videotaped interactions tasks. Ninety-two dyads were willing to participate and provided written informed consent. The present study used this subsample of mother-adolescent dyads.

Each year, mothers and adolescents were videotaped at home during conflict interaction tasks. Mothers and adolescents also filled out several questionnaires during the home visits. In addition to the written instructions, trained research assistants provided verbal instructions about the questionnaires. Families received €100 per home-visit. This study was approved by the medical ethics committee of the University Medical Center in Utrecht.

Conflict Interaction Task

Mothers and adolescents were asked to choose an issue that they discussed most often during the last month. We provided the Interpersonal Conflict Questionnaire (Laursen 1995), which lists topics of frequent family conflicts (e.g., chores, school problems, curfews), as an aid to selecting topics. Mothers and adolescents spent 10 min attempting to resolve the conflict issues, and their discussion was videotaped ($M = 7.88$ min; $SD = 1.9$).

Each conflict interaction task was coded using a simplified version of the SPecific AFfect coding system (SPAFF: Gottman et al. 1996). This modified SPAFF version has been applied successfully to parent–child interactions (e.g., Hollenstein et al. 2004). SPAFF identifies the affects expressed during parent–child interactions through a combination of verbal content, voice tone, facially expression, and physical cues. Coders categorized the affects displayed using four positive codes (affection, enthusiasm, humor, interest), five negative codes (complaining, sadness, fear, anger, contempt), and a neutral code (refers to statements and information exchange that are non-emotional in content and voice tone). The 10 mutually exclusive affect codes were recorded continuously in real time for mothers and adolescents independently. Observational codes were recorded using The Observer XT 9.0 (Noldus Information Technology 2009).

Coders were trained intensively over a 3-month period to achieve a minimum inter-observer criterion of 75 % agreement and .65 kappa. To maintain these criteria, weekly discussion meetings were conducted. Twenty percent of the videotaped interactions were independently coded by two coders to provide estimates of reliability. Coders were unaware which sessions were used to assess observer agreement. The average inter-observer agreement over five waves was .71 kappa.

Measures

Dyadic Variability Measures

The data of the conflict interactions of each dyad at each wave were plotted on state space grids in GridWare 1.15a (Lamey et al. 2004). This program plots the real-time

emotions (SPAFF codes) during the conflict interactions of mother-adolescent dyads on state space grids. A grid represents all possible emotional combinations of a mother-adolescent dyad. The mother's coded emotions are plotted on the x-axis and the adolescent's emotions are plotted on the y-axis. Each cell on the grid represents a potential emotional state of the dyad. A trajectory is plotted through the successive dyadic points on the grid in the same order as the emotions proceed in real time. Thus, a grid represents a sequence of dyadic emotional states. The state space grids for the present study consisted of 100 cells, because to each dyad member 10 possible emotions or SPAFF codes were available during the conflict discussions.

Three state space grid measures of dyadic variability were derived from GridWare 1.15a (Lamey et al. 2004) for each dyad at each wave. First, the *total number of unique cells* (TUC) refers to the total number of unique emotional states the dyad occupied during the interaction (Granic et al. 2003). A high TUC score indicates that the dyad behaved more flexibly during the interaction, because they occupied more cells on the grid. When dyads have a low TUC value they remain in the same emotional states for long periods of time, and therefore show less flexible interaction patterns.

Second, *dispersion* assesses the spread of emotional states of the dyad across cells. More specifically, it refers to the sum of the squared proportional duration across all cells adjusted for the total number of cells in the grid. Dispersion values were inverted to create a dispersion range from 0 to 1 (Granic et al. 2007). Dyads with dispersion values close to 0 show behavior in few cells, and dyads with dispersion values close to 1 show emotions in many cells. This means that dyads with high dispersion levels show more variability in their emotions. The formula that was used by GridWare to calculate dispersion is: $1 - [(n \sum (di/D)^2) - 1]/[n - 1]$. D refers to the total duration of the interaction, di is the duration in cell i on the grid, and n indicates the total number of possible cells on the grid. The TUC and Dispersion measures have been shown to exhibit good reliability and moderate predictive validity (Granic et al. 2007; Hollenstein et al. 2004). The present study also showed moderate stability of these measures over time. For TUC, correlations ranged from .41 to .56 ($p < .01$), and for Dispersion correlations ranged from .34 to .46 ($p < .01$).

Third, *duration entropy* measures the organization and predictability of interaction patterns, and it specifically refers to the level of dyadic transitions between different emotional states. Duration entropy was calculated in GridWare with the formula: $\sum (Pi * \ln(1/Pi))$. Pi refers to the probability of a single time-unit occurring in a state, which is calculated by dividing the duration of an

emotional state by the total duration of the interaction. High entropy reflects high levels of dyadic variability; there is a high level of dyadic transitions between different emotions on the grid. These dyads thus visit cells on the grid for shorter periods of time resulting in less organized and less predictable dyadic emotions. When dyads display low duration entropy this indicates more dyadic rigidity; cells on the grid are visited for longer periods of time which makes dyadic emotions more organized and predictable. The moderate to high correlations ($r = .32$ to $r = .60$, $p < .01$) between waves in the present study indicated stability of the duration entropy measure.

Questionnaire Measures

Aggressive Behavior The physical aggression subscale of Morales and Crick's (1998) revised self-report measure of aggression and victimization (see Linder et al. 2002) also assessed adolescents' aggressive behavior. Adolescents rated six items on a 7-point Likert scale, ranging from "not at all" to "very true". Example items are: "I try to get my own way by physically intimidating others" and "When someone has angered or provoked me in some way, I have reacted by hitting that person". Higher scores indicate higher levels of aggressive behavior. The Cronbach's alphas at the different measurement waves were good; they ranged from .88 to .89.

Perceived Autonomy Support The balanced relatedness scale (Shulman et al. 1997) was used to measure the perceived autonomy support of mothers and adolescents. This scale assessed the extent to which mothers felt that they accepted the opinions, wishes, and needs of the adolescent, and the extent to which adolescents felt that their mother accepted their opinions, wishes, and needs. The questionnaire consisted of seven items that were answered on a four-point scale (i.e., 1 = absolutely disagree to 4 = absolutely agree). Mothers and adolescents independently judged to what extent the seven items characterized their relationships. For example, mothers had to answer the following statements: "I respect my child's decisions" and "I consider my child's opinions". Adolescents had to answer statements such as: "My mother respects my decisions", and "My mother considers my opinion". For each wave the seven items were averaged to compute separate mean composite scores for mothers and adolescents. Previous research supported the validity and reliability of the instrument (Shulman et al. 1997). In this study, Cronbach's alphas of perceived autonomy support over the five measurement waves ranged from .82 to .89 for mothers and from .83 to .91 for adolescents.

Perceived Conflict Frequency Perceived conflict frequency between mothers and adolescents was measured using the Interpersonal Conflict Questionnaire (Laursen 1995). Both mothers and adolescents independently rated whether they had an argument or fight with each other over the past 7 days. They rated 10 issues on a 5-point Likert scale, ranging from never to often. Examples of items are "responsibilities", "personal freedom", "relationships", "homework", and "annoying behavior". We averaged the 10 items to compute separate conflict frequency mean scores for adolescents and mothers. Cronbach's alphas over the five measurement waves ranged from .86 to .92 for mothers, and from .85 to .88 for adolescents.

Strategy of Analyses

To examine whether there are distinct developmental trajectories of dyadic variability from age 13 to 17, we conducted Multivariate Latent Class Growth Analyses (MLCGAs). To be able to conduct these MLCGAs, we first determined whether changes over time in the dyadic variability measures were linear or quadratic by performing Univariate Latent Growth Models (LGMs) for the three measures of variability separately. We conducted MLCGAs in Mplus 6.1 (Muthén and Muthén 2010). MLCGA summarizes longitudinal data by modeling individual-level variability in developmental trajectories through a small number of classes that are defined by unique sizes and shapes (Nagin 2005). This means that we modeled the development of dyadic variability from age 13 to 17, and examined whether certain types of mother-adolescent dyads tend to have distinctive developmental trajectories of dyadic variability over the five waves. We performed MLCGAs on the three variability measures TUC, duration entropy, and dispersion simultaneously, because these three indicators represent dyadic variability, or the range of dyadic emotional states, in a slightly different way. Correlations between TUC and dispersion ranged from .65 to .74 ($p < .01$) across waves, correlations between TUC and duration entropy ranged from .78 to .82 ($p < .01$) across waves, and correlations between dispersion and duration entropy ranged from .95 to .97 ($p < .01$) across waves.

Several criteria were used to determine the number of classes or trajectories in the MLCGAs. First, when comparing models the Sample Size Adjusted Bayesian Information Criterion (SSA-BIC) should be lowest for the most optimal model. Second, we used the Lo-Mendell-Rubin Likelihood Ratio Test (LMR-LRT; Lo et al. 2001) to determine whether a model with k classes is significantly better than a model with $k-1$ classes. Third, we utilized entropy as an index of classification accuracy. (Please note that entropy in the MLCGA is different from the variability measure duration entropy). Entropy values range

from .0 to 1.0, with values of .75 and higher indicating accurate classifications. Finally, the theoretical meaningfulness and interpretability should be satisfactory. If an additional trajectory was found to be a slight variation of a trajectory already found in a lower class solution, we chose the most parsimonious model. Also, every group had to cover at least 5 % of the sample for meaningful interpretation and further analysis (Muthén and Muthén 2000; Nagin 2005). Furthermore, to validate that more dyadic variability referred to a broader emotional repertoire of both positive and negative affect and was not restricted to a specific affect, we performed LGMs for positive and negative affect separately.

To examine whether the dyadic variability trajectories showed distinct initial levels and change rates of aggressive behavior, perceived autonomy support, and perceived conflict frequency between ages 13 and 17, we performed multigroup LGMs controlling for gender. The dyadic variability trajectory membership was thereby entered as a grouping (or moderating) variable in these analyses. We ran the models for adolescents' aggressive behavior, adolescents' and mothers' perceived autonomy support, and adolescents' and mothers' perceived conflict frequency separately. Firstly, we determined with LGMs what shape of growth applied best to each model. We examined this for the dyadic variability trajectories separately. Secondly, we compared unconstrained with constrained models to test whether intercept and slope values could be constrained to be equal for the different dyadic variability trajectories.

To determine the goodness-of-fit of the LGMs, we used the following global fit measures: Chi-Square/degrees of freedom (χ^2/df) ratio, Comparative Fit Index (CFI), and the Root Mean Square Error of Approximation (RMSEA). According to Kline (2005), a good fitting model is one in which the χ^2/df ratio is less than 3, the CFI is larger than .90, and the RMSEA is smaller than .10. We conducted model comparisons using Robust χ^2 difference tests (Satorra and Bentler 2001). When examining the growth

shape of a model we selected the model that significantly improved the model fit, and when examining parameter constraints, we selected the model that did not significantly impair the model fit. Additionally, relatively higher CFI's and lower RMSEA's indicated a better model fit.

Results

Development of Dyadic Variability During Adolescence

It appeared from the LGMs that linear models fitted best for all three variability measures TUC ($\Delta\chi^2_{SB2}(1, N = 92) = 1.74, p = .187$), duration entropy ($\Delta\chi^2_{SB2}(1, N = 92) = 2.37, p = .124$), and dispersion ($\Delta\chi^2_{SB2}(1, N = 92) = 0.40, p = .556$). Consequently, we specified linear slopes in the MLCGAs. MLCGAs with one through four classes were estimated. The multivariate two-class model seemed to fit the data best, because for this model the SSA-BIC was lowest (1535.57), the LMR-LRT was significant ($285.72, p < .01$), and entropy was acceptable (.89). Also, adding a third and a fourth class to the model did not provide unique information (i.e., trajectories were found to be a variation of one of the trajectories in the 2-class solution), and it resulted in trajectories of less than 5 % of the sample. Due to the relatively small sample size it was not possible to use multigroup MLCGAs to examine gender differences. However, the distribution of gender of the two dyadic variability classes showed a comparable distribution to that of the total sample.

Table 1 provides estimates of mean intercepts and mean linear slopes. The two variability classes were meaningfully different on these growth parameters. The first class (Low variability dyads, $n = 48$) was composed of dyads who displayed lower levels of dyadic variability on all three measures and they remained stable in dyadic variability from age 13 to 17. The second class (High decreasing variability dyads, $n = 44$) showed higher levels

Table 1 Intercepts and linear slopes for the two class solution

	Low variability dyads		High decreasing variability dyads	
	<i>B</i>	95 % CI	<i>B</i>	95 % CI
Intercepts				
TUC	7.25***	[6.23, 8.23]	11.89***	[10.96, 12.83]
Dispersion	.25***	[0.19, 0.26]	.41***	[0.37, 0.45]
Duration entropy	.53***	[0.46, 0.61]	1.00***	[0.92, 1.09]
Linear slopes				
TUC	−0.25	[−0.51, 0.02]	−0.85***	[−1.24, −0.45]
Dispersion	−.01*	[−0.02, 0.00]	−.04***	[−0.05, −0.03]
Duration entropy	−.02*	[−0.04, −0.01]	−.07***	[−0.10, −0.05]

TUC total unique number of cells, CI confidence intervals

* $p < .05$, ** $p < .01$,

*** $p < .001$

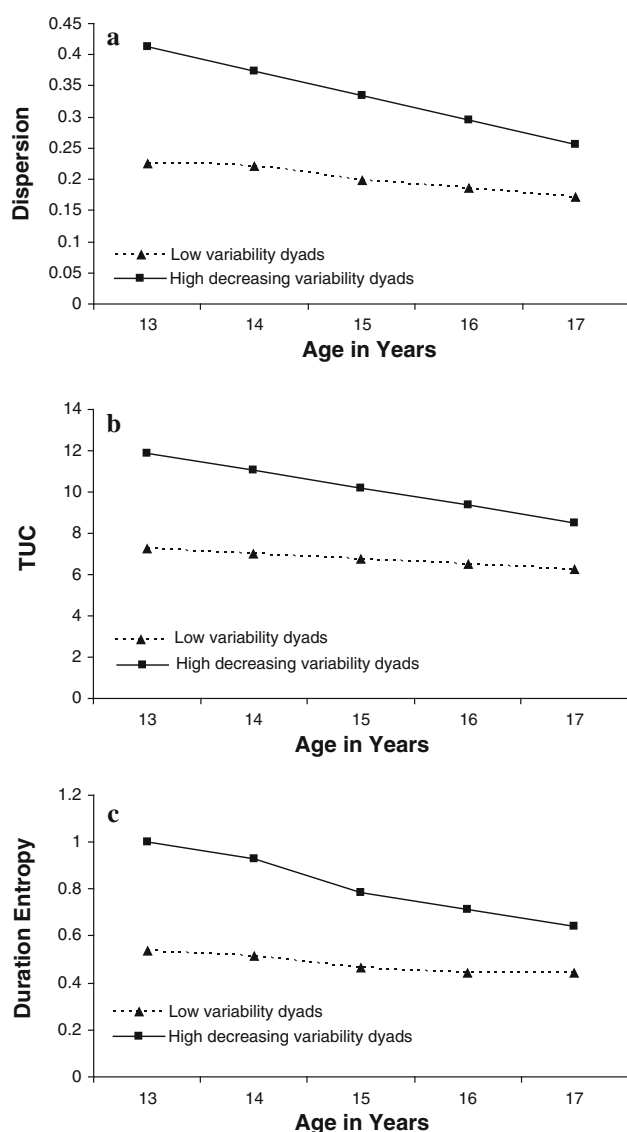


Fig. 1 A graphical presentation of the mean trends of the two dyadic variability classes for dispersion (a), total number of unique cells (TUC) (b), and duration entropy (c)

of dyadic variability over time than the first class, and a downward trend in the three dyadic variability measures from age 13 to 17. Figure 1 provides a graphical

presentation of the mean trends for the two dyadic variability trajectories per variability measure.

Additionally, LGMs fitted the data well for both positive ($\chi^2(20) = 12.395$, $CFI = 1.00$, $RSMEA = .00$ (90 % $CI = .000-.092$)) and negative affect ($\chi^2(20) = 14.331$, $CFI = 1.00$, $RSMEA = .00$ (90 % $CI = .000-.081$)). The results indicated in line with the definition of variability, that high decreasing variability dyads initially showed more negative and positive affect (mean intercept negative affect = .20; $SE = .01$, $p < .001$; mean intercept positive affect = .10; $SE = .01$, $p < .001$) than low variability dyads (mean intercept negative affect = .07; $SE = .01$, $p < .001$; mean intercept positive affect = .06; $SE = .01$, $p < .001$). Furthermore, between age 13 and 17, high decreasing variability dyads significantly decreased in negative affect (mean slope = $-.03$; $SE = .01$, $p < .001$), but low variability dyads showed stable and low levels of negative affect (mean slope = $-.01$; $SE = .00$, $p = .316$). Thus, the initial differences between the two types of dyads in the level of negative affect became smaller during adolescence. Finally, as high decreasing variability dyads (mean slope = $-.01$; $SE = .01$, $p = .017$) and low variability dyads (mean slope = $-.01$; $SE = .01$, $p < .016$) showed a similar significant decrease in the level of positive affect between age 13 and 17, the high decreasing variability dyads showed consistently more positive affect between age 13 and 17 than the low variability dyads.

Development of Dyadic Variability, Adjustment, and Relationship Quality

Our main aim was to examine differences between low variability dyads and high decreasing variability dyads in the development of adolescents' aggressive behavior, adolescents' and mothers' perceived conflict frequency, and adolescents' and mothers' perceived autonomy support. We controlled for gender in the analyses. Fit statistics of the final models are presented in Table 2 and regression coefficients in Table 3. Figure 2 provides a graphical presentation of the mean trends for the two dyadic variability trajectories of aggressive behavior, perceived

Table 2 Fit statistics of univariate multigroup LGMs for aggressive behavior, perceived autonomy support, and perceived conflict frequency

	$ML\chi^2$	df	CFI	RMSEA	90 % CI RMSEA
Aggressive behavior	18.00	21	1.00	.000	[.000, .104]
Mothers' perceived autonomy support	31.41	27	.98	.060	[.000, .135]
Adolescents' perceived autonomy support	25.17	21	.92	.066	[.000, .147]
Mothers' perceived conflict frequency	18.74	28	1.00	.000	[.000, .048]
Adolescents' perceived conflict frequency	43.59	27	.99	.029	[.000, .126]

$ML\chi^2$ Robust Maximum Likelihood estimation of Chi-Square, df degrees of freedom, CFI comparative fit index, $RSMEA$ root mean square error of approximation, CI confidence interval

Table 3 Growth factors of univariate multigroup LGMs of aggressive behavior, perceived autonomy support and perceived conflict frequency

	Intercept			Linear slope			Quadratic slope		
	<i>M</i>	σ^2	95 % CI <i>M</i>	<i>M</i>	σ^2	95 % CI <i>M</i>	<i>M</i>	σ^2	95 % CI <i>M</i>
Low variability dyads									
Aggressive behavior	1.64***	.68*	[1.45, 1.83]	−0.19**	.20	[−0.36, −0.01]	0.05**	.01	[0.01, 0.09]
Mothers' perceived autonomy support	3.30***	.06**	[3.21, 3.37]	0.01	.00	[−0.02, 0.03]			
Adolescents' perceived autonomy support	3.29***	.08	[3.22, 3.38]	−0.18**	.07	[−0.28, −0.05]	0.04*	.01	[0.01, 0.07]
Mothers' perceived conflict frequency	2.22***	.16**	[2.13, 2.37]	0.01	.01	[−0.04, 0.03]			
Adolescents' perceived conflict frequency	2.18***	.21**	[2.05, 2.31]	−0.04	.02*	[−0.09, 0.02]			
High decreasing variability dyads									
Aggressive behavior	1.64***	.56*	[1.45, 1.83]	−0.03	.02	[−0.09, 0.03]			
Mothers' perceived autonomy support	3.30***	.04**	[3.23, 3.36]	0.05***	.00	[0.02, 0.07]			
Adolescents' perceived autonomy support	3.29***	.12***	[3.21, 3.36]	−0.02	.01	[−0.05, 0.02]			
Mothers' perceived conflict frequency	2.22***	.38***	[2.13, 2.37]	0.01	.02	[−0.04, 0.03]			
Adolescents' perceived conflict frequency	2.18***	.16	[2.05, 2.31]	−0.08**	.00	[−0.14, −0.03]			

Quadratic slopes are only presented for the models where a quadratic trend was present. *M* mean, σ^2 variance, *CI* confidence interval

* $p < .05$, ** $p < .01$, *** $p < .001$

autonomy support, and perceived conflict frequency from age 13 to 17.

Aggressive Behavior

Fit statistics indicated that the shape of growth differed for the two types of dyadic variability dyads: for aggressive behavior a quadratic model fitted the low variability dyads best and a linear model fitted the high decreasing variability dyads best. Next, intercept values could be constrained to be equal between dyadic variability dyads ($\Delta\chi^2_{SB2}(1, N = 92) = 0.06, p = .809$). This indicated that adolescents of low variability and high decreasing variability dyads had similar initial levels of aggressive behavior. For the adolescents of low variability dyads there was a significant decrease in aggressive behavior from age 13 to 15, followed by a significant increase in aggressive behavior from age 15 to 17. In contrast, adolescents of high decreasing variability dyads showed stable levels of aggressive behavior from age 13 and 17 (see Table 3; Fig. 2).

Perceived Autonomy Support

For mothers' perceived autonomy support, a linear model fitted the data best for both low variability and high decreasing variability dyads (see Table 2). Intercept values could be constrained to be equal between dyadic variability dyads ($\Delta\chi^2_{SB2}(1, N = 92) = 2.78, p = .096$). However, the linear slope could not be constrained to be equal between dyadic variability dyads ($\Delta\chi^2_{SB2}(1, N = 92) = 7.24, p = .007$). These results indicated that mothers of low variability and high decreasing variability dyads perceived

similar initial levels of autonomy support, but differences in developmental pathways of autonomy support. Mothers of low variability dyads perceived stable levels of autonomy support over time, and they showed lower levels of autonomy support towards middle adolescence than mothers of high decreasing variability dyads. Mothers of high decreasing variability dyads perceived a significant increase in autonomy support over time (see Table 3; Fig. 2).

For adolescents' perceived autonomy support, fit statistics indicated that the shape of growth differed for the two types of dyadic variability dyads: a quadratic model fitted the low variability dyads best and a linear model fitted the high decreasing variability dyads best (see Table 2). Intercept values could be constrained to be equal between dyadic variability dyads ($\Delta\chi^2_{SB2}(1, N = 92) = 0.47, p = .493$). This indicated that adolescents of low variability and high decreasing variability dyads perceived similar initial levels of autonomy support, but differences in developmental paths of autonomy support. For adolescents of low variability dyads there was a significant decrease in perceived autonomy support from age 13 to 15, followed by a significant increase in perceived autonomy support from age 15 to 17. In contrast, adolescents of high decreasing variability dyads showed stable levels of perceived autonomy support over time, and they showed higher levels of autonomy support between age 14 and 16 than adolescents of low variability dyads (see Table 3; Fig. 2).

Perceived Conflict Frequency

For mothers' and adolescents' perceived conflict frequency, a linear model fitted the data best for both low variability dyads and high decreasing variability dyads (see

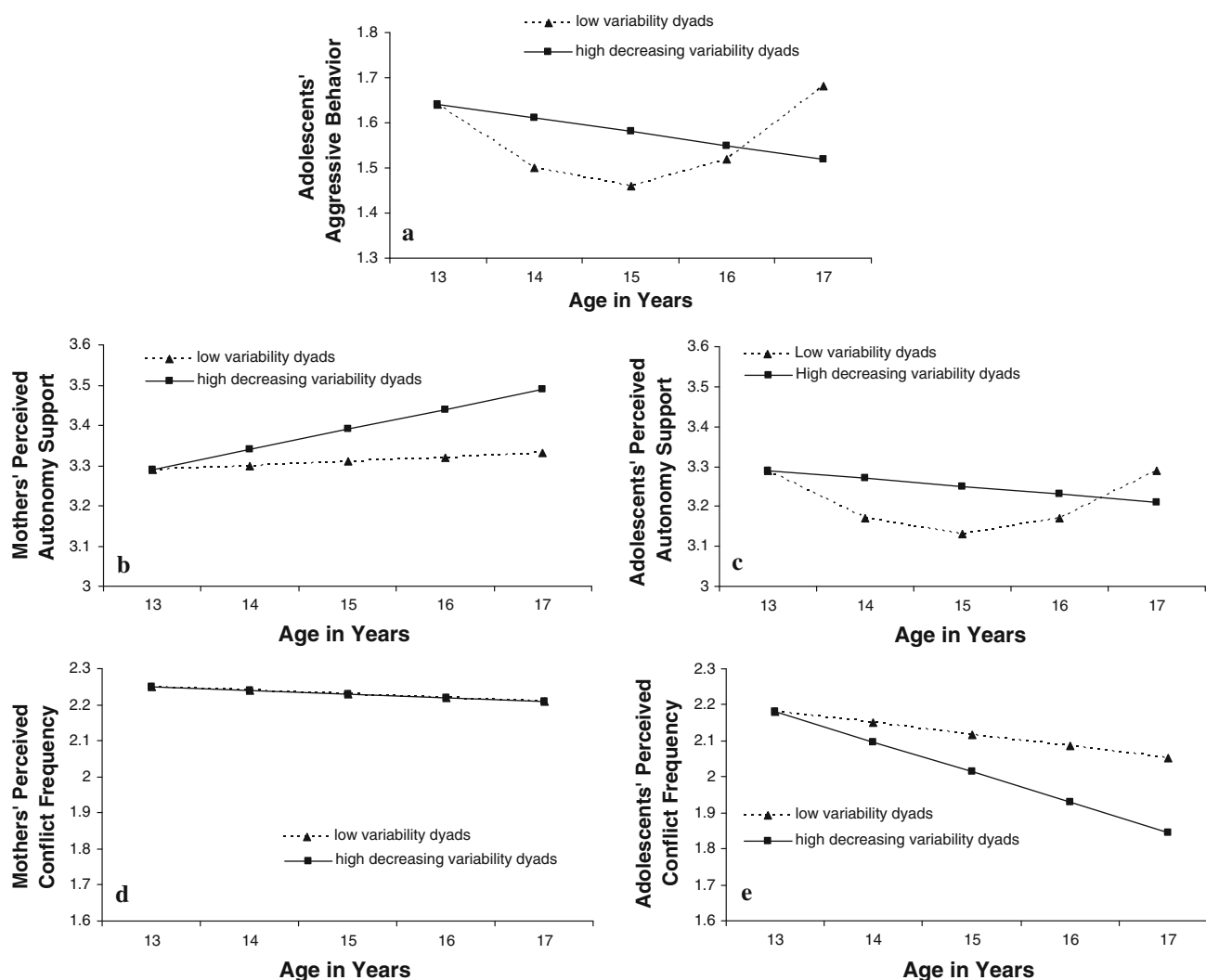


Fig. 2 Development of aggressive behavior (a), perceived autonomy support (b, c) and perceived conflict frequency (d, e) for low variability dyads and high decreasing variability dyads

Table 2). Intercept values could be constrained to be equal between dyadic variability dyads for mothers' perceived conflict frequency ($\Delta\chi^2_{SB2}(1, N = 92) = 0.39, p = .534$), and adolescents' perceived conflict frequency ($\Delta\chi^2_{SB2}(1, N = 92) = 1.15, p = .285$). This indicated that mothers and adolescents of low variability and high decreasing variability dyads perceived similar initial levels of conflict frequency at age 13 of adolescents (see Table 3; Fig. 2).

Slope values mothers' perceived conflict frequency could be constrained to be equal between dyadic variability dyads ($\Delta\chi^2_{SB2}(1, N = 92) = 0.24, p = .627$). The results indicated that mothers of low variability and high decreasing variability dyads perceived similar developmental paths of conflict frequency over time. Mothers of both types of dyads did not significantly change in their levels of perceived conflict frequency over time (see Table 3; Fig. 2). It was not possible to constrain the slope values between dyadic variability dyads for adolescents'

perceived conflict frequency ($\Delta\chi^2_{SB2}(1, N = 92) = 4.17, p = .041$). The results also suggested that there were differences in the developmental paths of adolescents' perceived conflict frequency. Adolescents of low variability dyads perceived stable levels of conflict frequency over time, and towards middle adolescence they perceived higher levels of conflict frequency than adolescents of high decreasing variability dyads. Adolescents in this latter type of dyads perceived a significant decrease in adolescents' conflict frequency over time (see Table 3; Fig. 2).

Discussion

The main goal of this observational study was to examine whether heterogeneity in the development of dyadic variability during mother-adolescent interactions was related to the development of adolescents' adjustment and

adolescents' and mothers' relationship quality. Adolescence is a developmental phase that is characterized by changes toward more egalitarian mother-adolescent relationships (De Goede et al. 2009; Pinquart and Silbereisen 2002). Conflict interactions are expected to trigger these relational reorganizations (Laursen and Collins 2009). Higher levels of dyadic variability during conflict interactions are thought to characterize periods of change and reorganization, and to be related to a more optimal reorganization of the mother-adolescent relationship (Granic 2005). Low levels of dyadic variability are suggested to be related to lower relationship quality and higher levels of adolescents' adjustment problems (Hollenstein et al. 2004; Lichtwarck-Aschoff et al. 2009). Therefore, we investigated whether changes in the structural organization of real-time interaction patterns during adolescence are related to developmental changes in the content of these relationships. The current study is one of the first examining heterogeneity in the development of dyadic variability and its associations with the development of psychosocial functioning over the course of adolescence.

Development of Dyadic Variability During Adolescence

By using a person-centered approach (Nagin 2005), this study found two types of mother-adolescent dyads that followed different developmental trajectories of dyadic variability: *low variability dyads* (52 % of our sample) and *high decreasing variability dyads* (48 % of our sample). Low variability dyads were characterized by stable and lower levels of dyadic variability during adolescence, indicating that these dyads maintained a limited emotional repertoire during conflict interactions throughout adolescence. High decreasing variability dyads were characterized by higher initial levels of dyadic variability, and decreasing levels of dyadic variability as adolescents grew older. Consistent with the definition of variability, these high decreasing variability dyads showed more positive and negative affect over time than low variability dyads. So, the high variability dyads seem to navigate adolescence with a broader emotional repertoire during conflict interactions.

From a dynamic systems standpoint (Fogel 1993; Thelen and Smith 1994), the broad range of emotional states of high decreasing variability dyads during early adolescence seems to suggest that these dyads are in the middle of reorganizing their interaction patterns. It is assumed that when dyads are able to express negative affect during interactions, but at the same time are able to display positive affect to each other, they may be better able to explore alternative interaction patterns and to renegotiate their relationship (Granic 2005; Izard 2009). Furthermore,

both theory (Granic et al. 2006) and empirical evidence (Granic et al. 2003) suggest that as mother-adolescent dyads pass through the transitional period of adolescence, interaction patterns become less variable. In our study, high decreasing variability dyads indeed showed a decrease in dyadic variability over the course of adolescence. In contrast, the small emotional repertoire of low decreasing variability dyads throughout adolescence is thought to indicate that these dyads did not go through a period of reorganization of interaction patterns (Granic 2005), which is further confirmed by the lack of change in perceived conflict frequency and the stable or even decreasing level of perceived autonomy support of these dyads. Future research needs to examine whether differential developmental patterns of dyadic variability also are related to differential changes in interaction patterns of dyads during adolescence. In short, the distinct developmental patterns of dyadic variability were associated differently with the development of psychosocial functioning from age 13 to 17.

Development of Dyadic Variability, Adjustment, and Relationship Quality

As expected, high decreasing variability dyads were characterized by a more optimal developmental profile of psychosocial functioning than low variability dyads. In line with our expectations, adolescents from low variability dyads showed increases in aggressive behavior over time, which extends previous results using younger age groups (Lunkenheimer et al. 2011). Although there are initial similarities in levels of aggressive behavior between low and high decreasing variability dyads, both dyads seem to navigate the transitional phase of adolescence with different levels of aggressive behavior. Although adolescents from low variability first reported decreases in aggressive behavior, towards middle adolescence they reported increases in aggressive behavior and eventually showed higher levels of aggressive behavior than adolescents from high decreasing variability dyads. It is thought that adolescents from dyads that do not have enough opportunity to learn to express, share, and regulate different types of emotions (Granic et al. 2007; Hollenstein et al. 2004) show higher levels of aggressive behavior (De Rubeis and Granic 2012; Silk et al. 2003). Our results suggest that the limited ability to express emotions during conflict discussions is associated temporarily with inhibited aggression but eventually to increased levels of aggression. The stable levels of aggressive behavior reported by adolescents from high decreasing variability dyads might indicate that they have learned to adequately use, share, and regulate different emotions over the course of adolescence (Silk et al. 2003). So, over the course of adolescence, the range of

emotional states of mother-adolescent dyads seems associated with the levels of aggressive behavior.

Furthermore, high decreasing variability dyads reported a better relationship quality than low variability dyads. Although there were no initial differences between both dyads, mothers and adolescents from high decreasing variability dyads started to show higher levels of autonomy support over time and adolescents from these dyads also reported lower levels of conflict over time. During adolescence, mothers and adolescents need to realign their autonomy perceptions and expectancies and for this it is important that mothers support the autonomy of adolescents (Laursen and Collins 2009). Our results suggest that high decreasing variability dyads seem to adjust to the growing autonomy needs of adolescents more adequately over the course of adolescence than low variability dyads, because they perceive more autonomy support over time than low variability dyads. Furthermore, the decrease in conflict frequency reported by adolescents from high decreasing variability dyads also may indicate that these dyads develop more egalitarian relationships over the course of adolescence. When power is more equally divided in the mother-adolescent relationship, conflicts are not so much needed anymore to convey discrepant perceptions (De Goede et al. 2009; Laursen and Collins 2009). In contrast, adolescents from low variability dyads reported stable and higher levels of conflict throughout adolescence, which in the long term is suggested to have a detrimental effect on the relationship and on psychosocial adjustment (Smetana 2011). Finally, it must be noted that mothers from high decreasing and low variability dyads did not differ with regard to their levels over time of perceived conflict frequency. This could be due to the fact that mothers often struggle with relinquishing power to adolescents and therefore experience interactions as more conflictual than adolescents do (Zimmer-Gembeck and Collins 2006). Overall, our results seem to suggest that mother-adolescent dyads with a broader emotional repertoire during interactions are characterized by changes over time towards a more egalitarian mother-adolescent relationship.

Limitations and Future Directions

Several limitations of this study should be noted and addressed in future research. It must be noted that both types of dyads may have experienced a peak in dyadic variability during pre or early adolescence (Granic et al. 2003), but our study started too late to be able to observe such a pattern. Given our promising results, it is important to examine heterogeneity of dyadic variability from childhood to late adolescence. Although our study is also unique in showing that distinct developmental pathways of

dyadic variability were associated with differential development of adolescent psychosocial functioning, our findings do not shed light on the developmental order between dyadic variability and psychosocial functioning. Future research should examine whether increases in mother-adolescent variability predict adaptive psychosocial functioning, or whether adaptive psychosocial functioning predicts the level of dyadic flexibility.

Furthermore, it is important to note that earlier research has employed different definitions of variability. It has been defined as the range of the emotional repertoire of a system (Lichtwarck-Aschoff et al. 2009), the number of changes in emotional states or the flexibility of a system (Granic et al. 2003), mean durations of emotional states or rigidity of a system (Hollenstein et al. 2004), and the predictability of system characteristics (Dishion et al. 2004). Although all these definitions refer to different structural aspects of a system, definitions have been used interchangeable. Even more so, some studies use a composite measure including multiple structural aspects of a system. To avoid confusion, the current study used only one definition of variability, namely the range of the emotional repertoire, because the nature and quality of emotions expressed during mother-adolescent interactions changes substantively over the course of adolescence (Eisenberg et al. 2009). Future research should also examine the development of other structural aspects of mother-adolescent interactions and its longitudinal associations with psychosocial functioning during adolescence.

Additionally, because gender differences have been found in levels of aggressive behavior and perceived relationship quality (Bongers et al. 2003; De Goede et al. 2009), we controlled for gender in our analyses. Our results showed that gender was not a significant predictor of intercept and slope differences in our analyses, and therefore it is unlikely that gender plays a role in the relationship between dyadic variability and psychosocial functioning. Finally, because the current study used a conflict discussion task to examine the structural organization of interactions over time, it seems prudent to investigate whether the same developmental profiles of dyadic variability are evident across diverse interaction contexts. Moreover, future studies should examine whether our findings can be generalized to other racial, ethnic, and socioeconomic populations.

Conclusion

The present study offers new and unique insights into the heterogeneity in the development of dyadic variability and its associations with the development of psychosocial functioning over the course of adolescence. First, a person

centered approach enabled us to identify two distinct developmental trajectories of dyadic variability during adolescence. Second, because we employed five consecutive annual waves of data from both observations and questionnaires of 92 mother-adolescent dyads, we were able to focus on both the structure and content of relationships, which provided a broader view on the longitudinal associations between dyadic variability and psychosocial functioning during adolescence. Taken together, these results paint a picture of high decreasing variability dyads that are characterized by a broader emotional repertoire, stable and lower levels of adolescents' aggressive behavior, and an increase in perceived relationship quality. In contrast, low variability dyads are typified by a smaller emotional repertoire, an increase in adolescents' aggressive behavior, and lower levels of perceived relationship quality over time. Observing dyadic variability in the emotional climate during interactions can help clinicians to distinguish adaptive from maladaptive mother-adolescent dyads. Our results also may help families understand how to adapt interaction patterns to developmental changes that take place during adolescence. For example, mothers often think that they have to suppress adolescents' negative emotional states, and encourage adolescents' positive emotional states. However, the current research suggests that adaptive interactions are marked by a wide range of emotional states and mothers should therefore guide adolescents during interactions in learning to express both positive and negative affect.

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